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PHYSICS.—*Anode resistance films.* JOHN T. TATE and PAUL D. FOOTE, Bureau of Standards.

In a previous paper[1] it was concluded that a polarization film of high resistance forms at the surface of a probe placed in the anode glow of a Wehnelt discharge tube. In the measurements referred to, the probe wire acted as an anode. It is of interest to compare the film resistance when the probe acts as an anode with that obtained when the probe acts as a cathode.

The experimental arrangement was that illustrated in the paper already referred to. For the probe as anode the same electrical connections were employed. For the probe as cathode the potentiometer and voltmeter readings were taken between the probe and the Wehnelt cathode. Resistances were computed in the manner previously described. The results of one series of measurements are represented by figure 1. For the same current flowing through the probe the film resistance is 4 to 6 times greater when the probe acts as a cathode than when it acts as an anode. The ratio of resistances $R_{\text{cathode}} : R_{\text{anode}}$ increases with increasing current through the probe. It has been generally assumed that the anode resistance film is negligible in magnitude as compared with the cathode resistance film. The small values of the ratio R_c/R_a observed are therefore of interest. It is also of interest to note that the ratio of the resistances of the cathode and anode films is of the same order of

[1] This JOURNAL 7: 482. 1917.

magnitude as the ratio of the cathode and anode falls of potential. The anode fall is usually about 20 volts and the cathode fall around 150 to 200 volts.

Further measurements were made upon anode resistance films in order to determine whether the resistance is inversely propor-

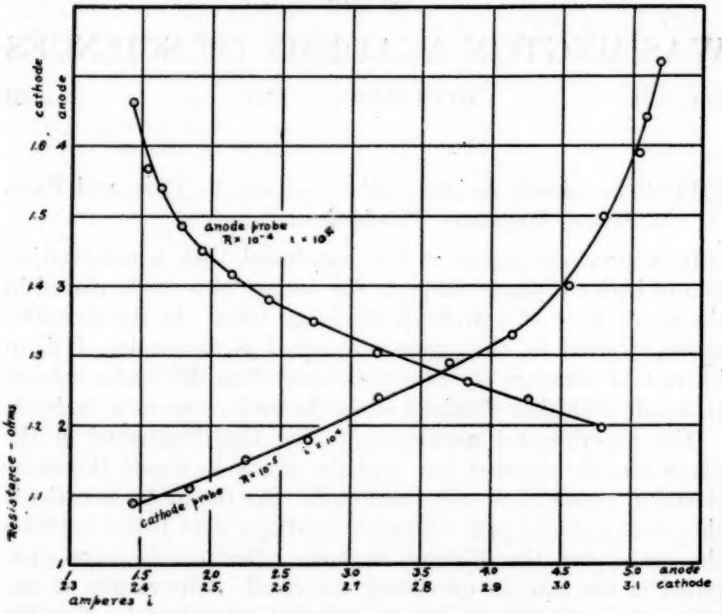

Fig. 1. Relation between surface resistance and current for probe acting as anode and as cathode.

tional to the area, a relation which would follow if the films acted as ordinary resistances. Two probe wires of the same diameter and having exposed areas in the ratio 1:2.28 were used in the place of R_p (fig. 1, p. 483). These could be operated as secondary anodes, either separately or shunted together. The resistances, R_1 of probe 1, R_2 of probe 2, and R_{1+2} of probes 1 and 2 connected, were measured in the manner previously described. The results of these measurements made with various current densities are given in table 1.

By the ordinary law of shunt resistances, if $R_1/R_2 = 2.3$ then R_1/R_{1+2} should equal 3.3, in agreement with the experimentally determined value. The ratio of areas of probes 1 and 2 was 1:2.28 while the observed ratio of resistances R_1/R_2 was 2.3:1. Hence the resistance of the polarization film varies inversely as its area.

TABLE 1

ANODE FILM RESISTANCE

R_1	R_2	R_{1+2}	R_1/R_2	R_1/R_{1+2}
ohms	*ohms*	*ohms*		
21,980	9,980	7,780	2.2	2.8
25,900	11,650	8,380	2.2	3.1
29,200	9,260	8,200	3.1	3.6
29,800	13,300	8,950	2.2	3.3
26,200	16,500	12,500	1.5	2.1
32,500	13,500	13,500	2.4	2.4
40,000	16,700	8,800	2.4	4.5
35,800	12,800	12,000	2.8	3.0
33,500	19,000	7,300	1.8	4.6
41,500	15,200	12,000	2.7	3.5
26,900	11,250	7,720	2.4	3.5
26,750	14,200	9,900	1.9	2.7
Mean.....			2.3	3.3

Conclusions. Further experimental work has confirmed the existence of an anode polarization film. The resistance of the anode film is less than that of the cathode film, and the two types of polarization resistance appear to be in a ratio of about the same order of magnitude as the ratio of anode to cathode fall of potential. The resistance of the anode film varies inversely with its area, but it should be emphasized that this relation was tested for wires of the same diameter. On account of changes which would be produced in the character of the field it is probable that the relation would not hold for wires of different diameters. Skinner has found entirely different values of resistance per square centimeter for wires of different diameters.

MINERALOGY.—*Tungstenite, a new mineral.*[1] By R. C. Wells and B. S. Butler, Geological Survey.

Although two sulphides of tungsten are described in textbooks of chemistry, none has hitherto been found as a mineral. It is therefore a pleasure to announce the discovery of tungsten sulphide as a prominent mineral in certain specimens of ore from the Little Cottonwood district, Utah. The analysis of the complex mixture in which tungsten sulphide occurs has proved unexpectedly difficult, so that it is not yet possible to state definitely the formula of the sulphide, although it is believed to be WS_2. As it will require considerable time to complete the necessary analytical determinations it seems advisable, in view of the unusual character of the material, to publish our preliminary results at this time. On account of the apparent resemblance to molybdenite in formula and some of its properties the new mineral has been named *tungstenite*.

The material in which tungstenite was found was given to Mr. V. C. Heikes, of the Salt Lake City office of the United States Geological Survey, by Mr. J. J. Beeson, geologist for the Emma Consolidated Copper Company, of Little Cottonwood district, Salt Lake County, Utah, with the suggestion that it be tested for selenium. Mr. Heikes forwarded the material to one of the writers (B. S. B.), who has been engaged in geological work in the district and who later, with F. C. Calkins, examined the deposit from which it came, though this was before the character of the mineral had been determined. The chemical examination and recognition of the tungsten sulphide was by the other writer (R. C. W.). No selenium could be determined, but on treating some of the material with aqua regia a yellow insoluble powder was noted and identified as tungstic oxide. Further study indicated that the tungsten is present as sulphide very intimately associated with a number of other minerals.

The Emma mine, from which the material was obtained, is located in the Little Cottonwood district, Salt Lake County, Utah, about 25 miles southeast of Salt Lake City. The mine was

[1] Published with the permission of the Director of the United States Geological Survey.

an important producer of lead-silver ores in the seventies. The ore shoot was followed until it was cut off by a fault. Attempts at the time to locate the continuation beyond the fault were unsuccessful and the mine was idle for many years. In 1916 Mr. Beeson by a detailed geologic study procured data that in 1917 led to the finding of the extension of the ore shoot. It was from this extension below the oxidized zone that the material here described was obtained.

TABLE 1

CHEMICAL ANALYSIS OF TUNGSTENITE (BY R. C. W.)

	PER CENT	FOR TENNANTITE AND TETRAHEDRITE	FOR PYRITE	FOR GALENA	FOR TUNGSTENITE	ATOMIC RATIO
W	44.7				44.7	1.00
S	29.1	2.5	9.2	0.6	16.8	2.18
Fe	8.8	0.8	8.1			
Zn	0.4	0.4				
Mn	0.6	0.6				
Ni	0.3	0.3				
Pb	4.1			4.1		
As	1.0	1.0				
Sb	0.8	0.8				
Cu	1.3	1.3				
Ag	0.4	0.4				
SiO_2	0.3					
H_2O	0.7					
Undetermined	7.5					
	100.0	8.1	17.3	4.7	61.5	

Two specimens of the material were examined chemically. The first specimen contained a much slickensided substance resembling graphite intimately associated with quartz, calcite, pyrite, gelena, and various accessory minerals. Tungstenite was identified in the slickensided material but it was not the only mineral present. The second specimen appeared to be much purer than the first and an average sample of it was analyzed with the results shown in table 1. This specimen was of a uniform gray color where it had been broken from a larger piece, but two sides were somewhat slickensided. On close examination

abundant small somewhat rounded grains of pyrite could be detected in it. A polished section revealed a little galena also. The analysis indicates tennantite and tetrahedrite, which were not distinguished in the single polished section of the material examined. A portion of the polished section which had a slightly bluish tinge was identified by microscopic reaction as tungstenite. The tungstenite is so soft that it wears away much faster than pyrite during polishing. The hardness appears to be about 2.5. Particles which are very easily cut from the massive piece with a knifeblade appear under the microscope to consist of feathery leaves or flakes resembling graphite. The mineral is opaque. It marks paper, soils the fingers slightly, and rubs up between a mortar and pestle like graphite. The cleavage and fracture could not be determined. The luster varies from dull to brilliant metallic; the color is dark lead gray; and the streak is dark gray. The actual specific gravity of the second specimen mentioned was 6.43. Allowing as well as possible for the impurities and undetermined material, the specific gravity of the tungstenite is calculated to be about 7.4. This may be compared with the following specific gravities, MoS_2 4.7, FeS_2 4.9, MoO_3 4.5, WO_3 6.3.

Tungstenite appears to be unattacked by hydrochloric acid or nitric acid. It is decomposed by aqua regia or by fusion with sodium nitrate. Its behavior in a bulb tube and on charcoal can not be stated definitely because of the impurities, though it appears to be a rather stable compound, not even being oxidized, by roasting in air. It burns with incandescence in oxygen.

Tungsten was determined by decomposing the ore with aqua regia. The solution was evaporated to dryness and the insoluble material taken up in dilute hydrochloric acid and filtered off. After extracting it with ammonium acetate to remove any lead sulphate present it was heated with ammonium hydroxide. A few per cent of residue remained insoluble in ammonia and contained some tungstic oxide, a little silica, some iron, and other material not yet determined. The filtered ammoniacal solution was evaporated to dryness and the residue was ignited and weighed as tungstic oxide. The other constituents were determined as in the analysis of tetrahedrite, after decomposing a portion of

the ore with chlorine in a hot tube. As the analysis stands the sample analyzed consists of 8.1 per cent of tennantite and tetrahedrite, 17.3 per cent of pyrite, 4.7 per cent of galena, and 61.5 per cent of tungstenite.

The geology of the district in which tungstenite has been found may be briefly summarized as follows: A series of Paleozoic limestones, shales, and quartzites, and pre-Paleozoic quartzites and shales, has been much broken by thrust faulting and subsequently intruded by quartz monzonite and quartz diorite which occur as stocks. Following the intrusion and accompanying mineralization there was much normal faulting and some reverse faulting.

The Emma ore body occurs as a replacement of a brecciated zone in Paleozoic limestone where it is crossed by a mineralizing fissure. The ore shoot follows the intersection of the breccia zone and fissure, pitching rather steeply to the northeast. About 450 feet below the outcrop the ore shoot is cut off by a strong fault, the continuation on the opposite side of the fault being about 250 feet lower. There is very little oxidized material in the portion of the shoot below the fault from which the tungstenite was taken.

The important vein minerals are quartz, galena, pyrite, tetrahedrite, argentite, and possibly some other silver minerals not yet determined. The detailed study of the ores will probably reveal other minerals. For a part of the shoot at least, the central portion consists mainly of rather fine-grained quartz that has almost completely replaced the limestone and that contains but relatively small amounts of metallic minerals. Surrounding this is a zone in which the limestone is less completely replaced and metallic minerals are more abundant.

Pyrite was the earliest metallic mineral to form in the deposit and this was followed by the galena, tetrahedrite, silver minerals, and tungstenite. The tungstenite is apparently in part contemporaneous with the galena and in part later than the galena. The fact that the specimens containing the most of this mineral have been found near a minor faulted zone suggests that there may have been an enrichment in tungsten along that zone, though that is not certain.

ABSTRACTS

Authors of scientific papers are requested to see that abstracts, preferably prepared and signed by themselves, are forwarded promptly to the editors. Each of the scientific bureaus in Washington has a representative authorized to forward such material to this JOURNAL and abstracts of official publications should be transmitted through the representative of the bureau in which they originate. The abstracts should conform in length and general style to those appearing in this issue.

GEOLOGY.—*Hydraulic-mining débris in the Sierra Nevada.* GROVE KARL GILBERT. U. S. Geological Survey Professional Paper 105. Pp. 154, with maps, sections, and illustrations. 1917.

Historical outline is given of the development of hydraulic mining in the Sierra Nevada, the encroachment of its tailings on valley lands, its subsequent restriction and regulation, and the circumstances leading to a study of the subject by the Geological Survey.

The tailings from hydraulic mines were in part deposited on neighboring slopes and in neighboring stream valleys and canyons and in part delivered to rivers that carried them forward. At the base of the range were large deposits on the piedmont slopes and other deposits in the beds of valley rivers. As a consequence of the piedmont and riverbed deposits rivers rose higher in time of flood and lands previously immune were inundated. The reclamation of basin lands and delta lands for agriculture by surrounding them with levees also aggravated flood conditions, and the results of the two causes were inseparable.

Comparison of maps of early and late dates shows that large deposits have shoaled the bays of the San Francisco system, and reduced their areas. These deposits, ascribed to hydraulic mining and to the increase of soil waste by agriculture and other industries, since the discovery of gold have amounted to more than 1100 million cubic yards.

The sand brought to the head of Suisun Bay by Sacramento and San Joaquin rivers is swept onward in the bays by tidal currents but is not believed to reach the Golden Gate bar in any appreciable quantity.

The stress that caused the restriction of hydraulic mining no longer exists. Under conditions to be created by works for the control of floods the capacity of valley rivers for transportation of débris will be increased, so that the mining might be partly resumed without preju-

dice to any valley interest except navigation. The important interest which now dictates that débris should be controlled is that of the commerce which traverses the Golden Gate. Possibilities for resumption of mining on a large scale, with storage of débris, lie in cooperation with irrigation and electric-power development for the control of Sierra streams. R. W. STONE.

GEOLOGY.—*Geologic history indicated by the fossiliferous deposits of the Wilcox group (Eocene) at Meridian, Mississippi.* EDWARD WILBER BERRY. U. S. Geological Survey Professional Paper 108-E. Pp. 12, with 2 plates and 2 figures. 1917.

This paper discusses briefly new and important additions to the flora of the Wilcox group and new evidence of the unconformity between the Wilcox and the Claiborne groups.

The conclusion seems justified that the upper Wilcox was a time during which the open sea became gradually smaller as the strand line moved southward, and that there was an interval of emergence between the deposition of the Wilcox and that of the Claiborne group, an interval whose considerable length is indicated by the great contrasts between the terrestrial floras and the marine faunas of the Wilcox and the Claiborne.

The two new species described are of especial interest in that the Nelumbo adds an entirely new type to the Wilcox flora, and the second adds a new cycad (Zamia), represented by fronds, the only known cycad from the American Tertiary except a single piece of a pinnule of another species of Zamia from the Wilcox. R. W. STONE.

GEOLOGY.—*A fossil flora from the Frontier formation of southwestern Wyoming.* F. H. KNOWLTON. U. S. Geological Survey Professional Paper 108-F. Pp. 35, with 13 plates. 1917.

This paper deals with a small but important fossil flora, now known to be of Colorado age, from the vicinity of Cumberland, Lincoln County, Wyoming. Although small in number of species, this flora offers information bearing on the physical and climatic conditions that prevailed in this region during early Upper Cretaceous time. It has also a possibly important biologic bearing, for it shows the presence of certain plant types that are now living in Polynesia. The plants described occur in what is now known as the Frontier formation.

The known flora from the Frontier formation near Cumberland embraces 25 forms, of which 7 are ferns, 1 an Equisetum, 1 a monocotyle-

don (Smilax), and the remaining 16 dicotyledons. They are entirely unlike anything now living in the New World and appear to find their closest relatives among species now living in Polynesia.

From the facts now available it appears unquestionable that at least the major portion of the Frontier formation was laid down in fresh water. The climate during Frontier time appears to have been tropical or subtropical. R. W. STONE.

GEOLOGY.—*The Bull Mountain coal field, Musselshell and Yellowstone counties, Montana.* L. H. WOOLSEY, R. W. RICHARDS, and C. T. LUPTON. U. S. Geological Survey Bulletin 647. Pp. 218, with maps, sections, and illustrations. 1917.

The Bull Mountain coal field came into prominence about 1906, when the westward extension of the Chicago, Milwaukee & St. Paul Railway was constructed through this part of Montana. This field is the chief source of fuel for this new transcontinental road and in consequence has been developed very rapidly, especially in the vicinity of Roundup.

The important coal-bearing formation is the Fort Union, which belongs to the lower part (Eocene series) of the Tertiary system. The rocks of this formation consist principally of massive, buff to yellowish-gray sandstone and light-colored clay shale. The lower 200 to 300 feet of the formation contains little coal.

The lowest formation outcropping in the Bull Mountain field is the marine Bearpaw shale, which is recognized in this part of Montana as the upper formation of the Montana group. The Lance formation overlies the Bearpaw shale and appears to be in conformable sequence with it. The Lance formation consists of alternating beds of yellowish-gray sandstone, drab, yellow, and gray clays, clay shale, and grayish sandy shale. Sandy material predominates. The lower part of the formation is noticeably micaceous; the upper part contains thin beds of coal.

The strata 200 to 300 feet thick immediately overlying the Lance and apparently conformable both with the Lance below and the upper part of the Fort Union above are known as the Lebo shale member. The member is conspicuous on account of its dark or olive-green color and the absence of the resistant sandstone which characterizes the overlying beds of the upper part of the Fort Union and the underlying Lance formation.

The upper part of the Fort Union formation occupies all of the center of the Bull Mountain region and contains the principal coal beds. It is composed of sandstone in beds ranging from a fraction of a foot to 50 feet or more in thickness, interbedded with a somewhat larger proportion of clay shale, shale, and numerous beds of coal.

Within the upper part of the formation there are 26 coal beds, ranging in thickness from 1 foot 2 inches to 15 feet. From the abundance of fossil leaves and fresh-water shells and the numerous beds of coal it is evident that the formation was deposited in fresh or nearly fresh waters, probably inland lakes or ancient estuaries on whose shores grew luxuriant vegetation.

All coal in this field may be classed as high-grade black lignite or subbituminous. Most of the coal beds are lenticular, showing a wide variation in thickness at different points on the outcrop. The coal beds are described and analyses given. The greater part of the volume is detailed description of the geology by townships. R. W. STONE.

GEOLOGY.—*Mineral resources of the Kantishna region, Alaska.* S. R. CAPPS. U. S. Geological Survey Bulletin 662–E. Pp. 53, with maps, sections, and illustrations. 1917.

The region discussed lies on the north side of the Alaska Range and includes portions of the basins of Nenana and Kantishna rivers.

The rocks of the Kantishna region range from highly metamorphic mica schists and gneisses, through less altered but deformed sediments of Paleozoic age, to the slightly indurated Tertiary coal-bearing beds and to the unconsolidated terrace gravels and the deposits of present streams.

The prevailing structural trend of the region is east-northeast, parallel to the axis of the Alaska Range, and has been determined by movements similar to those which brought the present range into existence.

The productive gold placer deposits of the Kantishna district all occur in the basins of the streams that head in the Kantishna Hills and radiate in all directions from the higher peaks. Paying deposits of gold placer gravel were found in 1905 and 1906 on all the streams that are now productive except Little Moose Creek.

The entire Kantishna mining district lies in an area in which the underlying rock is the Birch Creek schist, cut by relatively small bodies of intrusive rocks. Among these intrusives are some dikes and

stocks of granite prophyry and quartz porphyry that may be genetically related to the mineralized quartz veins. The largest and most continuous gold-bearing quartz veins that have been found are in the basins of those streams whose placers have yielded the most gold. This seems to be conclusive proof that the gold of the placer gravels was derived, at least in large part, by the erosion of the larger quartz veins that cut the schists. The local origin of the placer gold is also confirmed by the appearance of the gold itself.

In those portions of the region that were glaciated the erosion by the ice was sufficiently severe to disturb or remove the greater part of the preexisting gold placer deposits, so that any concentrated deposits of gold that are now present are due to the erosion by streams since the ice retreated.

A fact that has notably influenced the gold placer deposits in many valleys is the large volume of detrital material that has moved from the valley walls down the slopes and out upon the stream gravel deposits and the rapidity with which this movement takes place.

R. W. STONE.

GEOLOGY.—*Tungsten minerals and deposits.* FRANK L. HESS. U. S. Geological Survey Bulletin 652. Pp. 85, with maps, sections, and illustrations. 1917.

An attempt is made to gather into this bulletin the general facts about tungsten, the minerals in which it is found, the kinds of deposits from which these minerals are obtained, and other information, and to show by illustrations, colored and uncolored, the appearance of typical specimens of the various tungsten minerals.

Tungsten deposits seem to be invariably in or associated with granitoid rocks, though they may be associated with their prophyritic facies, and, so far as is known, only with the varieties that contain considerable quantities of free quartz, and usually if not always with the lighter-colored members.

Most of the tungsten deposits of the country are in the states that lie in and west of the Rocky Mountains—South Dakota, Montana, Colorado, New Mexico, Idaho, Utah, Arizona, Nevada, California, Oregon, and Washington—all of which contain at least small deposits. Wyoming is the only state in this whole great western area in which no tungsten is known to have been found. R. W. STONE.